



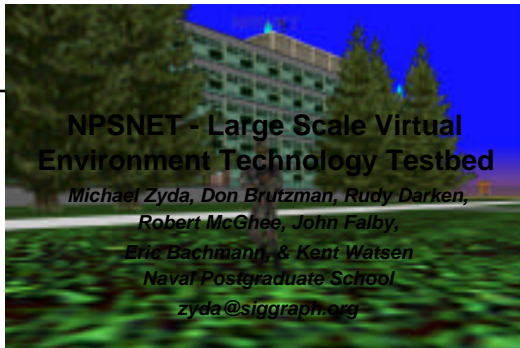
1998


# NPSNET - Large-Scale Virtual Environment Technology Testbed (presentation to Turk Silahlı Kuvvetleri (TSK) Modeling and Simulation Conference)



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**NPSNET - Large Scale Virtual Environment Technology Testbed**  
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**Talk Outline**

**NPSNET Research Group Overview**

- Techno - software technology for the networked VE.
- Interact - interaction technology for the networked VE.
- Apps - VE applications.

**Educational Infrastructure**

**External Activities**


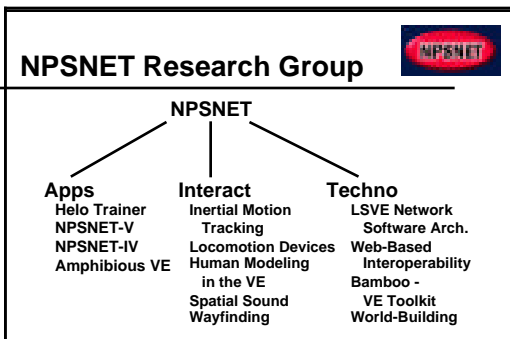



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**NPSNET Research Group**

*The focus of the NPSNET Research Group is on the complete breadth of human-computer interaction and software technology for implementing large scale virtual environments (LSVEs).*

*In addition, we apply that research in constructing VEs useful for the DoD.*



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**LSVE Network Software Architecture**

**LSVE - large scale virtual environment -**

- a networked virtual environment with greater than 1,000 players in it.

—When we say this large a number of players, we mean both live/interactive and autonomous/computer-generated characters.

## LSVE Network Software Architecture



### **Network Software Architecture (NSA) -**

- the combination of the network protocol used for the LSVE and the software architecture that supports that protocol within the confines of available bandwidth and processor cycles.
  - There are many protocol-only and software architecture-only solutions. There are few full NSA solutions.

## NSA for the VE Research Directions



### **Web-Based VE Interoperability**

- What are the issues?
  - What types of information need to be transferred between web-based networked VEs?
  - How do we transfer that information on the Internet (protocol)?
  - What is the NSA for this?

## Web-Based VE Interoperability



### **What types of information need to be transferred between networked VEs?**

- State changes/entity interactions (peer-to-peer).
- Heavy-Weight Objects (http client/server requests).
- Network pointers (URLs).
- Real-time streams (Mbone audio/video).

## Web-Based VE Interoperability



### **How do we transfer that information (protocol)?**

- Projects
  - Dial-a-protocol project (peer-to-peer).
  - virtual reality transfer protocol - vrtp (the applications-layer protocol used to wrap together dissimilar application layer protocols).

## Web-Based VE Interoperability



### **Dial-a-protocol project**

- Development of tools/methods for the rapid generation of peer-to-peer VE applications layer network protocols.
  - How do we formally specify the state change and entity interaction information?
  - How do we embed semantics in syntax in general? **How do we do this on-the-fly?**

## Web-Based VE Interoperability



### **Dial-a-protocol project**

- How do we formally specify the state change and entity interaction information?
  - DIS-Java-VRML
    - There is a working group working on how we provide DIS-like interoperability for the web. This is a fast-track effort with early success (1500 PDUs per second).

## Web-Based VE Interoperability



### Dial-a-protocol project

- How do we embed semantics in syntax in general?  
**How do we do this on-the-fly?**

–What we are looking at very much has the flavor of mobile agents.

Behavior is encoded in a packet.

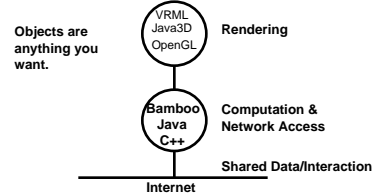
Syntax is (identifier type, number of bits).

Semantics is Java object & methods.

## Web-Based VE Interoperability



### General Entity Model



## Web-Based VE Interoperability



### How do we transfer that information (protocol)?

–The dial-a-protocol project looks at a very small piece of the peer-to-peer, light-weight entity interaction problem in networking VEs.

–If we go back and look at our list of types of information to be transferred between VEs, we see there are other types of data in our VE ...

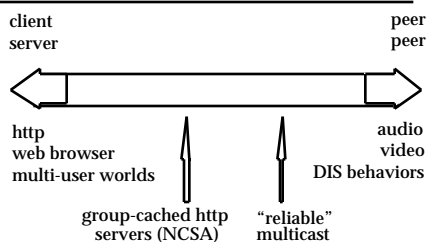
## Web-Based VE Interoperability



### virtual reality transfer protocol - vrtp

- the application-layer protocol used to wrap together dissimilar application layer protocols.
- vrtp will support:
  - Light-weight entity interactions (peer-to-peer).
  - Network pointers (URLs).
  - Heavy-weight objects (http client/server request).
  - Real-time streams (Mbone audio/video).

## vrtp - a full spectrum application layer protocol



## Web-Based VE Interoperability



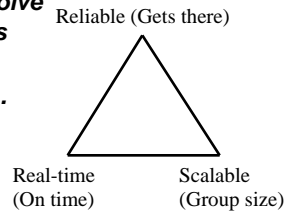
### What is the network software architecture for this?

- The primary problem we are trying to solve is how to optimize available bandwidth and available processor cycles for our LSVE.

## Constraints on the problem



***We are trying to solve a problem that has some pretty hard constraints on it ...***



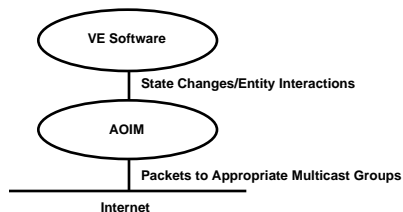
## Area of Interest Management



***We have performed a lot of software experimentation and systems testing to get a good understanding of the software architecture issues.***

- We are now focusing on a layer of software we call the Area of Interest Manager (AOIM).

## Area of Interest Management



## Area of Interest Management



### ***State Changes/Entity Interactions***

- instead of being broadcast to everyone, are assigned to particular multicast groups (groups are interested parties, spatial partitioning, functional partitioning, temporal partitioning, ...).

## Area of Interest Management



### ***Packets to Appropriate Multicast Groups***

- Multicast groups are subscribed to by appropriate parties.
- Packets not part of subscribed multicast groups are killed off at the network interface unit rather than at the applications layer in the CPU!
- So your VE only gets packets from groups formally subscribed to.

## Area of Interest Management



### ***Research Issues in AOIMs***

- How do we program in a **general way** an AOIM?
- AOIMs are application dependent. How do we design such systems for dynamic AOIM replacement?
- In a distributed fashion, how do we dynamically assign information to a particular set of multicast groups?

## Persistent Universes



*In the recent NRC report "Modeling and Simulation: Linking Entertainment and Defense", it is pointed out that a key component technology missing from most of today's VEs is that of the ability to maintain a persistent universe.*

## Persistent Universes



*A persistent universe is one in which participants can enter/leave the virtual environment at any time, returning to prior states as last left on exit.*

## Persistent Universes



*The design of the technology that allows persistence in the virtual world is intertwined with that of the VE network software architecture.*

*We plan to develop a software architecture that supports such persistence.*

## Additional things that are also important ...



- Quality of service for all types of VE information flow.
- Latency & predictive modeling.
- Heterogeneous VE interoperability.
- Authoring tools that are network based/aware.
- High speed WAN for VE research ...

## DoD Standards for Interoperability



*The NPSNET Research Group has always been on the leading edge in the development and utilization of DoD standards for interoperability.*

- NPSNET-IV is SIMNET and DIS compliant.
- We are currently evaluating HLA for its utility in interactive LSVEs.

## Bamboo - An Extensible Framework for Networked VEs



### **Motivation:**

- A general-purpose, cross-platform, high-level toolkit providing a framework facilitating VE application research and development.

## What is Bamboo?



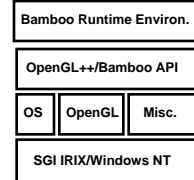
- Core mechanisms common to networked VEs.  
–an API toolkit for serious programmers.
- Dynamically extensible runtime environment.  
–an application which puts it all together.
- Based on OpenGL++, C++, and ACE.

## How to extend OpenGL++?



***Bamboo sits along-side rather than on top of OpenGL++ ...***

***Based on Plug-ins***



## Bamboo's Mechanisms



<i>Extensibility</i>	<i>Device Manager</i>
<i>Networking</i>	<i>Database Handling</i>
<i>Security</i>	<i>Statistics Manager</i>
<i>Process Management</i>	<i>Graphical User Interface</i>
<i>Inter-Process Communication</i>	<i>Undo/Redo</i>
<i>Remote Procedure Calls</i>	<i>Physically-Based Modeling</i>
<i>Callbacks</i>	<i>Friendly OpenGL++</i>
<i>Event Handling</i>	<i>Abstractions</i>

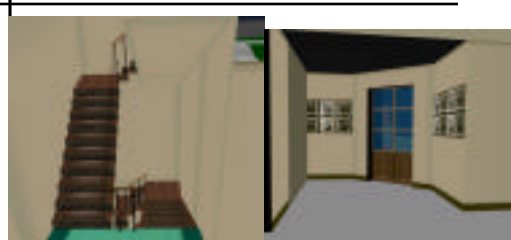
## VE World Building



## VE World Building



## VE World Building



## **Interact**



***Inertial Motion Tracking of Humans in a Networked VE***

***Locomotion Devices***

***Human Modeling in the VE***

***Spatial Sound***

***Wayfinding***

## **Inertial Motion Tracking of Humans in a Networked VE**



***Current technologies are unable to provide a natural and intuitive interface for inserting a human into a large scale networked virtual environment.***

## **Inertial Motion Tracking of Humans in a Networked VE**



***Advances in the design of micromachined accelerometers and angular rate sensors and 3D spatial positioning using RF, present the possibility of tracking human body motion inertially in a manner similar to that of an inertial navigation system (INS).***

## **Inertial Motion Tracking of Humans in a Networked VE**



***Current human motion capture systems suffer from numerous limitations:***

- User encumbrance
- Restricted Range
- Susceptibility to Interference
- Latency
- Shadowing

## **Inertial Motion Tracking of Humans in a Networked VE**



***The hybrid inertial tracking system is essentially sourceless and does not suffer from these limitations.***

***Inertial body tracking is based upon same algorithms as inertial navigation of missiles, aircraft and ships.***

***Physics resemble those of the human vestibular system.***

## **Inertial Motion Tracking of Humans in a Networked VE**



***Proposed tracking system advantages:***

- High data rates without perceptible lag.
- Tolerant to environmentally induced errors.
- Will produce consistent registration between physical and virtual worlds.
- Allow multiple users in a large working volume simultaneously.



## Inertial Motion Tracking of Humans in a Networked VE



### **Basic Concept:**

- Instrument the Human body with 15 micromachined inertial sensors.
- Each sensor contains:
  - Three-axis accelerometer.
  - Three-axis rate sensor.
  - Three-axis magnetometer.

## Inertial Motion Tracking of Humans in a Networked VE



*Complementary filtering would correct for sensor errors and drift.*

*The sensors would provide an orientation vector for each body segment.*

*RF positioning of a single point on the body would accurately place the articulated human within the VE.*

## Inertial Motion Tracking of Humans in a Networked VE



### **Human Body Tracking Sensor Configuration**



## Locomotion Devices



*Most of our work in locomotion devices has been to integrate other people's locomotion devices into the NPSNET-IV software platform.*

*Two of our most successful demos ...*

## AUSA 95 Treadport



**Joint project with Sarcos Engineering, UPENN & NPS.**

- NPS role was to integrate treadport into NPSNET-IV.



## AUSA 96 Omni Directional Treadmill (ODT)



## Human Modeling in the VE



***We have explored commercial solutions for animating articulated humans in the VE.***

- UPENN Jack-ML
- BDI DI-Guy
- All of these solutions are too slow once you get above about 5 to 10 humans in view.

## Human Modeling in the VE



***Low-cost, articulated humans.***

- We want to develop articulated human support software capable of displaying 100 to 150 humans in the NPSNET-V VE.



## Spatial Sound for the VE



***Virtual Environment Auditory & Visual Intersensory Modality Issues***

- Measuring performance & immersion during wayfinding and target acquisition tasks in a VE.
  - Are manipulating both auditory & visual display fidelities.
  - Want to find out the effects of both modalities on performance & immersion.

## Wayfinding in the VE



***Training Spatial Knowledge Acquisition Using Virtual Environments***

- The goal of the work is to show that VEs can be used to acquire spatial knowledge of a specific real space (training transfer).

## Wayfinding in the VE



- Future work will involve the investigation of environmental features and perceptual stimuli and their role in navigation and wayfinding so that we may understand how to degrade the fidelity of a VE without substantially degrading navigation performance.
- We will then extend these concepts to training general navigation skills, including map usage (perspective transformation) and landmarking abilities.

## Applications of VE Technology



***NPSNET-IV Completion***

***NPSNET-V***

***An Amphibious VE***

***Helo Training***

## NPSNET-IV Completion



### **NPSNET-IV**

#### **Capabilities**

- Building walkthroughs.
- Articulated humans - mounting/dismounting capability.
- Networking - play across the multicast backbone of Internet.
- Terrain database integration, terrain paging (70km x 70km).
- Any vehicle capability - air, ground, articulated human.
- Testbed for VE NSA issues.
- Interoperability - SIMNET/DIS
  - Constructive model integration - Janus World Modeler
  - ModSAF

## NPSNET-ODT Press Conference & AUSA 96



## NPSNET-V



### **Features & Plans**

- Redesigning the network software architecture of NPSNET.
- Plug & play VE where additional modules of capabilities (networking, human models, terrain models, walkthroughs, mounting/dismounting of humans, general interaction ...) can be developed with a uniform, published API.

## NPSNET-V



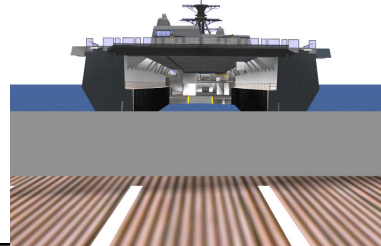
### **Technologies for NPSNET-V**

- Bamboo - Next Generation Toolkit
  - OpenGL++
  - C++/Java
  - vrtp & HLA

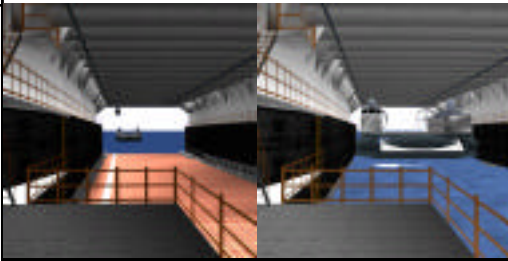
### An Amphibious VE



### An Amphibious VE



### An Amphibious VE



### An Amphibious VE



### Educational Infrastructure



***MS & PhD Program in Computer Science,  
with specialization in Computer Graphics  
& Visual Simulation***

### Educational Infrastructure - MOVES Curriculum



#### ***Modeling, Virtual Environments & Simulation Curriculum***

- The MOVES Curriculum provides the MS and Ph.D. student both fundamental & specialized courses in applied computer simulation technology & the application of quantitative analyses to human-computer interaction in simulation technology.

## Educational Infrastructure - MOVES Curriculum



- There are two tracks that support the curriculum's research efforts, the Visual Simulation Track and the Human-Computer Interaction Track.
  - The Visual Simulation track is focused on developing the technology for VEs.
  - The Human-Computer Interaction track is focused on evaluating human performance with the developed technology.

## NRC CSTB - Modeling & Simulation Linking Entertainment & Defense



### *Modeling & Simulation: Linking Entertainment & Defense*

ISBN 0-309-05842-2

National Academy Press

[http://www.nap.edu/  
readingroom](http://www.nap.edu/readingroom)



## Mobile Agents - Explanations & Examples



### *Mobile Agents - Explanations & Examples*

William R. Cockayne &  
Michael Zyda

ISBN 1-884777-36-8

Available from Manning  
Press

<http://www.manning.com>



## Networked Virtual Environments



### *Networked Virtual Environments*

Sandeep Singhal &  
Michael Zyda

- ACM Press



## NPSNET Research Group Sponsors



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**Advanced Networks  
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## NPSNET Web Sites



### **NPSNET Page**

<http://www.npsnet.nps.navy.mil>

### **Interact Page**

<http://www.npsnet.nps.navy.mil/interact>

### **Michael Zyda**

<http://www.cs.nps.navy.mil/people/faculty/zyda>